Trace Metal Levels in Bivalves and Crabs From Alice Arm, Hastings Arm and Observatory Inlet, B.C.

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ABSTRACT

Farrell, M.A. and M.D. Nassichuk, 1984. Trace Metal Levels in Bivalves and Crabs from Alice Arm, Hastings Arm and Observatory Inlet, B.C. Canadian Data Report of Fisheries and Aquatic Sciences, No. 467, vii + 42 p.

Alice Arm, the southern terminus of Observatory Inlet in Northern British Columbia, is the site of the Amax of Canada Ltd. Kitsault molybdenum mine. When operating, the mine discharges approximately 12,000 tons of tailings daily into Alice Arm from a submerged outfall located between Roundy and Lime Creeks. This discharge has created considerable concern, arising in part from the potential for trace metal accumulation in marine organisms which are traditionally harvested in recreational, commercial and native food fisheries in the area. This study which examined trace metal concentrations in cockles and crabs from Alice Arm, Hastings Arm, and Observatory Inlet was initiated in response to these concerns.

The findings are compared (where applicable) with Health and Welfare standards for acceptable trace metal levels in edible fish tissue, as well as with values reported in the literature for bivalves from other coastal locations in British Columbia and elsewhere in the world.

Key Words: Shellfish, cockles, crabs, trace metals, Amax of Canada Ltd., Alice Arm, Hastings Arm, Observatory Inlet, B.C.

RÉSUMÉ

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La mine de molybdène Kitsault de l'Amax of Canada Ltd. est située au bras Alice, la partie la plus au sud de l'inlet Observatory (nord de la Colombie-Britannique). Quand elle est en exploitation, cette mine rejette environ 12,000 tonnes de résidus chaque jour dans le bras Alice à partir d'un point de décharge immergé situé entre les ruisseaux Roundy et Lime. Ces rejets ont soulevé beaucoup d'inquiétudes basées en partie sur la possibilité d'une accumulation de métaux traces dans les organismes marins qui sont traditionnellement exploités dans le cadre des pêches récréative, commerciale et autochtone de la région. La présente étude, qui porte sur les concentrations de métaux traces dans les coques et les crabes des bras Alice et Hastings et le l'inlet Observatory, a été amorcée en réaction à ces préoccupations.

Les concentrations déterminées lors de l'étude sont comparées avec les valeurs des normes de Santé et Bien-Être Social pour les teneurs acceptables de métaux traces dans les tissus des produits de la pêche comestibles, ainsi qu'avec les valeurs signalées dans les publications pour les bivalves d'autres régions côtières de la Colombie-Britannique ou ailleurs dans le monde.

Mots-clés: mollusques, coques, crabes, métaux traces, Amax of Canada Ltd., bras Alice, bras Hastings, inlet Observatory, Colombie-Britannique.

INTRODUCTION

Alice and Hastings Arms, located approximately 144 km north of Prince Rupert, are glacial fed fjords approximately 18.5 km in length which form the terminus of Observatory Inlet.

Observatory Inlet has been the site of a number of active mines. Between 1911 and 1972 nine mines operated in the area and produced 388,000 tons of copper, gold, silver, lead and molybdenum (Littlepage, 1978). The most recent mining activities in Alice Arm include the B.C. Molybdenum mine which operated from 1966 to 1972, and the Amax of Canada molybdenum mine at Kitsault which operated from April 1981 to October of 1982, at which time operations were suspended for an indefinite period as a result of a depressed molybdenum market. In contrast to previous operations in the area, tailings from the Kitsault mine are discharged directly to Alice Arm from a submerged outfall at a depth of 50 metres. During the initial 19 months of operation slightly more than 4 million tonnes of tailings from the Amax mine were deposited on the bottom of Alice Arm. This discharge has aroused considerable concern, particularly among individuals who have traditionally harvested fish and shellfish in recreational, commercial and native food fisheries in Observatory Inlet.

A review of the available data on metal levels in biological tissue was undertaken by Burling et al. (1983) as part of a continuing technical assessment of the Amax mine discharge . This review concluded that of the four species groups sampled (algae, bivalves, crustacea and fish) only bivalves show indications of elevated tissue trace metal concentrations. Among the bivalves examined the panel noted there have not been any apparent increases in tissue metal levels among intertidal and

upper sub-tidal filter feeding specimens since the tailings discharge commenced in 1981. These findings are consistent with trace metal chemistry data which indicates that soluble trace metal levels in the water column and sediment pore waters are very low (Burling et al., 1983). On the other hand, deposit feeding bivalve samples collected at depths of 50 m or more all show early indications of tissue trace metal elevations consistent with patterns of sediment metal enrichment associated with the tailings discharge.

While the species traditionally harvested in this area do not typically include benthic deposit feeders, concerns about metal contamination continue to be expressed, in part because of the uncertainty regarding the potential for bioaccumulation in organisms of commercial or recreational value over the long term.

This investigation was conducted in response to these concerns, and presents results of tissue metal analyses for cockles (Clinocardium nuttallii), King crabs (Lithodes aequispina, and Paralithodes camtschatica) and Tanner crab (Chionoecetes bairdi) collected in October-November 1983 and February 1984 from Alice and Hastings Arms, and Observatory Inlet.

The tissue metal levels reported herein were examined in reference to applicable Health and Welfare Canada guidelines and regulations for acceptable trace metal concentrations in edible fish tissue. The cockle tissue metal data were also compared to data for bivalves previously collected from coastal waters of B.C. and from other selected coastal locations throughout the world.

Comparisons between tissue metal levels in crabs from Alice Arm and other coastal locations throughout the world have been previously reported in Futer and Nassichuk (1983).

MATERIALS AND METHODS

SAMPLE COLLECTION

The study area is presented in Figure 1; sampling stations in Hastings and Alice Arm, and Observatory Inlet are presented in Figure 2. All sampling was conducted between October 1983 and February 1984.

Cockles (Clinocardium nuttallii) were collected in February 1984 by SCUBA divers from a depth of approximately 6-7 m at Davies Point in Observatory Inlet. This sampling location was chosen following discussions with Nishga band members who identified this as the traditional native harvesting site for clams and cockles in Alice Arm and Observatory Inlet.

Tanner crab (Chionoecetes bairdi), Golden king crab (Lithodes aequispina) and Red king crab (Paralithodes camtschatica) were collected from Alice and Hastings Arm in October and November 1983 by otter trawl and baited crab traps.

The trawling gear consisted of two otter doors attached to a net with a 5.8 m throat and 3.8 cm mesh body. Trawls were conducted with a scope of 3:1 over an average distance of 0.8 to 1 km at a speed of 2.5 knots. Otter trawl coordinates and depths are presented in Table 2.

Commercial king crab pots (dimensions: 18 x 1.8 x 0.9 m) were baited with frozen herring which were placed in perforated plastic containers in the center of each trap. Crab pot sampling locations, collection depths and pot soak times are presented in Table 3.

SAMPLE PREPARATION

Cockles

The cockles (Clinocardium nuttallii), which ranged from 6.5 to 8.7 cm in length were placed in acid cleaned plastic depuration trays in clean seawater and allowed to depurate for 21-24 hours.

Following depuration, all organisms were examined, and moribund or dead specimens were discarded. The shells of the remaining cockles were wiped clean of algal matter, rinsed in clean water, placed in individual plastic bags and frozen.

Upon receipt in the laboratory cockles were measured for both anterior-posterior and dorsal-ventral length. Soft body parts were excised carefully from the shells (using an acid cleaned plastic scalpel), placed in individual whirlpac bags, weighed and submitted for analyses.

Crabs

Carapace lengths and widths for each crab were determined at the time of collection. All adhering algae and sediments were washed off the carapace and weights (in shell) were recorded. All tissue dissections were performed on live animals within 1 hour of collection. The organisms were dissected on a bed of crushed ice under a laminar flow hood to reduce handling and metabolic stress and minimize contamination of the samples. Dissection utensils were acid washed and rinsed twice in double deionized water prior to use.

Sufficient muscle tissue was removed from the second walking leg of each crab to provide a minimum of 5 g wet weight tissue.

LABORATORY ANALYSES

The procedures for sample preparation and metal analyses other than mercury were those outlined in Government of Canada, (1979) Environmental Laboratory Manual.

Metal analyses was performed by the joint DOE/DFO laboratory in West Vancouver, B.C. A list of all metals analyzed and their detection limits is given in Appendix I. Certified reference tissue standards (NBS-1566 and 1577) were concurrently analyzed (Appendix II) to confirm the accuracy and precision of tissue analytical results.

In preparation for analysis, all samples were blended in a Waring blender until homogenous. Each sample was weighed, freeze dried, reweighed and then ground. Aliquotes of approximately 0.3 grams of dried tissue were then brought into solution using wet ashing techniques (low temperature ash followed by treatment with nitric acid (HNO_3), hydrochloric acid (HCl) and heat).

Tissue samples for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn) were determined by atomic emission spectrometry (AES) using a Jarrell-Ash FLA 100, 850 Inductively Coupled Argon Plasma-Optical Emmission Spectometer (ICAP). Fine definition for cadmium and lead was obtained using flamless atomic absorption spectrometry.

Tissue samples for mercury analyses were homogenized, freeze dried and placed in a 100 ml reaction tube. A subsample (0.1 ± 0.005 g) was weighed and the tissue digested in 10.0 ml of concentrated sulphuric acid. The sample was then oxidized in 4.0 ml hydrogen peroxide and heated. One ml of nitric acid was

then added to the colorless digest and brought to a standard volume with 50 ml of water. The samples were analyzed on a Mercury Monitor (Pharmacia Model 1205).

Wet weight tissue metal values were determined by multiplying dry weight metal values by the ratio of wet: dry tissue weight calculated for each sample analyzed.

RESULTS AND DISCUSSION

Table 1 lists the organisms analyzed for metal content.

The Canadian Health and Welfare guidelines and Food and Drug regulations for acceptable trace metal concentrations in fish/shellfish are presented in Appendix III. The existing regulations, which apply only to arsenic and lead, refer specifically to the metal concentrations in extractable dried fish protein. As trace metal concentrations in dried fish protein and metal content in edible fish or shellfish tissue are not directly comparable, the tissue metal data presented herein have not been examined in reference to these regulations.

In contrast, the administrative guideline for the maximum acceptable mercury concentrations in edible wet weight fish tissue is directly comparable to the wet weight mercury concentrations in muscle tissue presented in this report.

COCKLES: GENERAL

Table 2 presents length and weight data for each of the thirty cockles analyzed. Concentrations of selected trace metals in individual cockles are presented on both a dry weight and wet

weight basis (Tables 4 and 5). Cockle tissue metal data previously reported from Alice Arm and Davies Point are presented in Appendix IV. Trace metal concentrations in other representative bivalves from Alice Arm, various southern coastal sites in British Columbia and selected coastal locations throughout the world were obtained from the literature and are presented in Appendices V and VI, respectively, for comparison with the data obtained in this study.

Arsenic

The mean arsenic concentrations in cockles could not be calculated as a number of samples contained levels that were less than detectable limits. Arsenic concentration (wet weight) in cockles ranged from <0.6 to 1.4 ug/g. The dry weight arsenic concentration in cockles ranged from <4 - 10 ug/g. These values are comparable to those reported in Mya arenaria and Mytilus edulis from Alice Arm in 1980 and 1982 respectively, and are similar to the results reported for both species of cockles taken from Davies Point and Alice Arm in 1982 (Appendix IV and V). The available information regarding arsenic concentrations in bivalves from other locations is extremely limited, however the values reported herein are comparable to levels reported for bivalves from other Canadian locations (Appendix VI).

Cadmium

The mean cadmium level in cockles was 0.19 ± 0.06 and ranged from 0.12 to 0.45 ug/g (dry weight). These concentrations are considerably lower than values reported for cockles from Alice Arm in 1982 and other bivalves from the south coast of B.C. and elsewhere in the world (Appendices IV, V and VI). Cadmium is not a regulated substance in edible fish tissue.

Chromium

The mean concentration of chromium (dry weight) in cockles was 1.2 ± 0.4 ug/g and ranged from 0.6 to 2.3 ug/g. These concentrations are comparable to or lower than those reported in the literature for bivalves from other coastal locations throughout the world (Appendix VI). Chromium is not a regulated substance in edible fish tissue.

Copper

The mean wet weight value for copper in cockles was 0.61 ± 0.14 and ranged from 0.44 to 1.21 ug/g. The mean dry weight concentration was 4.0 ± 0.9 and ranged from 3.0 to 8.0 ug/g. These concentrations are comparable to those reported for cockles from the same location in 1982 and are typically lower than values reported for other bivalves from southern B.C. with the exception of scallops (Appendices IV and V). The values reported herein are somewhat lower than those reported in bivalves from the United Kingdom, California and Tasmania, and are similar to tissue copper levels reported in clams from Oregon, New York and Hong Kong (Appendix VI).

Copper has not been a regulated substance in edible fish tissue since 1979.

Lead

Lead values for cockles ranged from 0.021 to 0.095 ug/g (wet weight) with a mean concentration of 0.046 ± 0.017. The mean dry weight lead content in cockles was 0.30 ± 0.10 and ranged from 0.16 to 0.62 ug/g. These values cannot be directly compared to previously reported values for lead in cockles from Davies Point

and bivalves from southern B.C. locales (Appendix IV and V) as the detection limits for lead in fish tissue varied considerably between these studies. The values reported for cockles in this study are however considerably lower than concentrations reported in bivalves from other coastal locations throughout the world (Appendix VI).

Manganese

The mean dry weight manganese concentration in cockles was 10.1 ± 4.3 ug/g (range 2.75 to 17.5 ug/g). These values are comparable to those reported in mussels and oysters from other locations around the world (Appendix VI). Acceptable levels of manganese in edible fish tissue are not regulated.

Mercury

Mercury (wet weight) concentrations in cockles ranged from 0.003 to 0.010 ug/g. The mean wet weight mercury content in cockle tissues was 0.007 ug/g. These concentrations are typically much lower than those reported in bivalves from other locations in southern B.C. and elsewhere in the world (Appendix V and VI) and are also well below the Health and Welfare Canada administrative guideline (0.5 ug/g) for acceptable mercury concentrations in edible wet weight fish tissue.

Molybdenum

Molybdenum concentrations in cockles were typically below detectable limits of 0.4 ug/g dry weight. Very little data are available regarding molybdenum concentrations in bivalves from other coastal locations worldwide. The available tissue data from Alice Arm would indicate that the molybdenum concentrations

in cockles reported herein are comparable to or lower than values previously reported for bivalves from Alice Arm or Observatory Inlet (Appendix IV and V). Molybdenum is not a regulated substance in edible fish tissue.

Nickel

The mean dry weight value for nickel in cockles was 6.5 ± 0.4 (range, 3.0 to 13 ug/g). These values are comparable to those reported in oysters, clams and mussels from other locations around the world (Appendix VI). Nickel is not a regulated substance in edible fish tissue.

Zinc

Zinc values for cockles ranged from 50.5 to 96.0 ug/g (dry weight). The mean zinc concentration of 64 ± 1 ug/g (dry weight) reported in this study is similiar to values reported for this species collected from Davies Point in 1982 (Appendix IV), and is typically less than values reported for bivalves from other locations worldwide (Appendix VI). Zinc content of edible fish tissue has not been regulated since 1979.

CRABS: GENERAL

Table 5 presents carapace length, weight and sex data for each of the 22 crabs examined. The concentrations of selected trace metals in individual crabs are presented on both a dry and wet weight basis in Tables 6 and 7 respectively, for comparison with previously reported tissue metal levels in crustaceans from Alice Arm, Observatory Inlet and other coastal locations (Futer and Nassichuk, 1983; Harbo and Birtwell, 1983; Harbo et al., 1983). Futer and Nassichuk (1983) present tissue metal data for King and

Tanner crab collected from Alice Arm and Observatory Inlet in 1981, however comparisons between the 1981 data and present data must be viewed cautiously as sampling locations, sample size and tissue metal detection limits vary considerably between these studies.

Arsenic

Mean wet weight arsenic values in crab muscle tissue ranged from 7.55 ± 2.10 ug/g (Red King crab) to 26.0 ± 18.1 ug/g (Tanner crab). The Golden King crabs had a mean wet weight arsenic concentration of 25.5 ± 6.07 ug/g. Mean dry weight arsenic concentrations ranged from 43.7 ± 14.3 ug/g (Red King crab) to 154.3 ± 99.2 ug/g (Tanner crab). The mean dry weight arsenic concentration in Golden King crab was 149.2 ± 30.5 ug/g.

The arsenic tissue concentrations reported in Red King crab from Hastings Arm in 1983 are very similar to the concentrations reported in individuals of this species collected from Observatory Inlet in 1981 (Futer and Nassichuk, 1983). In contrast the arsenic values in Tanner crabs collected from Alice Arm in 1983 were higher than those reported in individuals from Observatory Inlet in 1981 (Futer and Nassichuk, 1983).

Cadmium

The mean dry weight cadmium concentrations in King crabs ranged from 0.23 ± 0.08 ug/g (Red King) to 0.35 ± 0.42 ug/g (Golden King) crab. The mean dry weight cadmium concentration in Tanner crab could not be determined as values below the detection limits of 0.04 ug/g precluded calculation of means and standard deviation. The highest cadmium concentration in crab muscle tissue was 1.4 ug/g which was reported in a Golden King crab from Hastings Arm.

Comparison between 1981 crab cadmium tissue concentrations (Futer and Nassichuk, 1983) and the present data are not possible as many of the 1981 reported values were less than analytical detection limits. In addition, the detection limits for cadmium obtained by graphite furnace analyses in 1983 are considerably lower than those obtained in 1981 which further complicates comparisons between 1981 and 1983 data. The mean dry weight cadmium values in Golden King crab are however very similar to the levels reported in this species prior to tailings discharge (1974-1977) and during mine operation (1981) (Littlepage, 1978; Goyette and Christie, 1982).

Chromium

Mean dry weight values for chromium in crabs ranged from <0.4 ug/g (Golden King crab) to 0.6 ± 0.15 (Red King crab). Tanner crab had a mean dry weight chromium concentration of 0.56 ± 0.05 ug/g.

These values are comparable to or lower than the chromium concentrations reported in Red King crab from Alice Arm and Observatory Inlet in 1981 (Futer and Nassichuk, 1983). Chromium is not a regulated substance in edible fish tissue.

Copper

Mean dry weight copper concentrations in the three species of crabs examined ranged from 24.8 ± 4.7 ug/g (Tanner crab) to 84.1 ± 22.1 ug/g (Red King crab). The mean dry weight copper concentration in Golden King crab was 50.6 ± 26.9 ug/g (wet weight). These values are similar to those reported in King and Tanner crabs collected from Alice Arm and Observatory Inlet in 1981 (Futer and Nassichuk, 1983). Copper has not been a regulated substance in edible fish tissue since 1979.

Lead

The mean dry weight lead concentrations in both species of King crab could not be determined as many of the reported values were below the detection limits of 0.08 ug/g. Tanner crab lead concentrations ranged from 0.2 to 0.37 ug/g (dry weight), and had a mean of 0.3 ug/g. Lead values for Red King and Tanner crab reported in the 1981 survey (Futer and Nassichuk, 1983) ranged from <3.8 - <4.0 ug/g (dry weight). Accordingly, comparisons between the 1981 and the 1983 data for these species reported herein are not possible. The highest dry weight lead concentration reported in Golden King crab from Alice Arm was 0.12 ug/g, which is comparable to or less than the levels reported in this species in 1980 and 1981 (Goyette and Christie, 1982).

Manganese

The mean dry weight manganese concentration in crabs ranged from 1.12 ± 0.34 ug/g (Red King crab) to 7.6 ± 5.18 ug/g (Tanner crab). The mean manganese concentration in Golden King crabs was 2.69 ± 1.52 ug/g dry weight.

The manganese concentrations in Red King crab are similar to those reported in 1981 whereas Tanner crab concentrations in 1983 were considerably higher than those reported in this species in 1981 (Futer and Nassichuk, 1983). Manganese is not a regulated substance in edible fish tissue.

Mercury

Mercury (wet weight) concentrations in all three species of crab were consistently less than 0.06 ug/g. The highest mean mercury concentration in crab muscle tissue was 0.035 ± 0.015 ug/g which

was reported in Tanner crab. The mean wet weight mercury concentrations in King crabs ranged from 0.011 ± 0.006 to 0.028 ± 0.018 in Golden King and Red King crabs respectively. The concentrations of mercury in crab muscle tissue are well below the recommended Health and Welfare guideline of 0.5 ug/g mercury in edible wet weight fish tissue.

Molybdenum

Molybdenum values for crab muscle tissue ranged from less than detectable (0.4 ug/g) to 0.6 ug/g (dry weight). The maximum dry weight molybdenum value reported was 0.6 ug/g in two Red King crabs taken from Hastings Arm.

All crab samples collected in 1981 were reported to contain less than detectable concentrations of molybdenum, however the differences in detection limits between 1981 and 1983 precludes comparisons between these data. Molybdenum is not a regulated substance in edible fish tissue.

Nickel

Nickel concentrations in crabs were consistently below the detectable limits of 2.0 ug/g (dry weight).

The values reported for King and Tanner crab collected from Alice Arm and Observatory Inlet in 1981 were also below detectable levels (Futer and Nassichuk, 1983) however the differences in detection limits between these surveys prohibits comparisons of the data. There are no regulated levels for acceptable nickel concentrations in edible fish tissue.

Zinc

Mean dry weight zinc concentrations in crab ranged from 121.7 (Tanner crab) to 196.3 ug/g (Red King crab) Golden King crab zinc concentrations ranged from 170 to 238 ug/g dry weight (mean of 192.8 ug/g.)

These concentrations are comparable to those reported in King and Tanner crab collected from Alice Arm and Observatory Inlet in 1981 (Futer and Nassichuk, 1983).

Zinc concentrations in edible fish tissue have not been regulated in Canada since 1979.

CONCLUSION

In general the levels of trace metals in crabs and cockles are within the range of concentrations found in similar species from other locales worldwide. With the possible exception of arsenic, the trace metal concentrations in these species would not be expected to represent a health hazard to consumers.

With specific reference to arsenic concentrations in crabs, the levels reported in Golden King and Tanner crab were considerably higher than those in Red King crab, however, the concentrations are similar to those reported in these species in 1978, 1980 and 1981 (Goyette, 1981; Goyette and Christie, 1982). These data would therefore indicate that there has not been any significant elevation to date in tissue arsenic concentrations of the commercially and recreationally important Golden King or Tanner crab of the area as a result of the Amax tailings discharge.

Any assessment of health hazards posed by the consumption of shell fish with the arsenic levels reported herein requires knowledge of consumption rates, shellfish contributions to the total diet and metal speciation (ie. organic versus inorganic forms of arsenic). This assessment is beyond the purview of this study.

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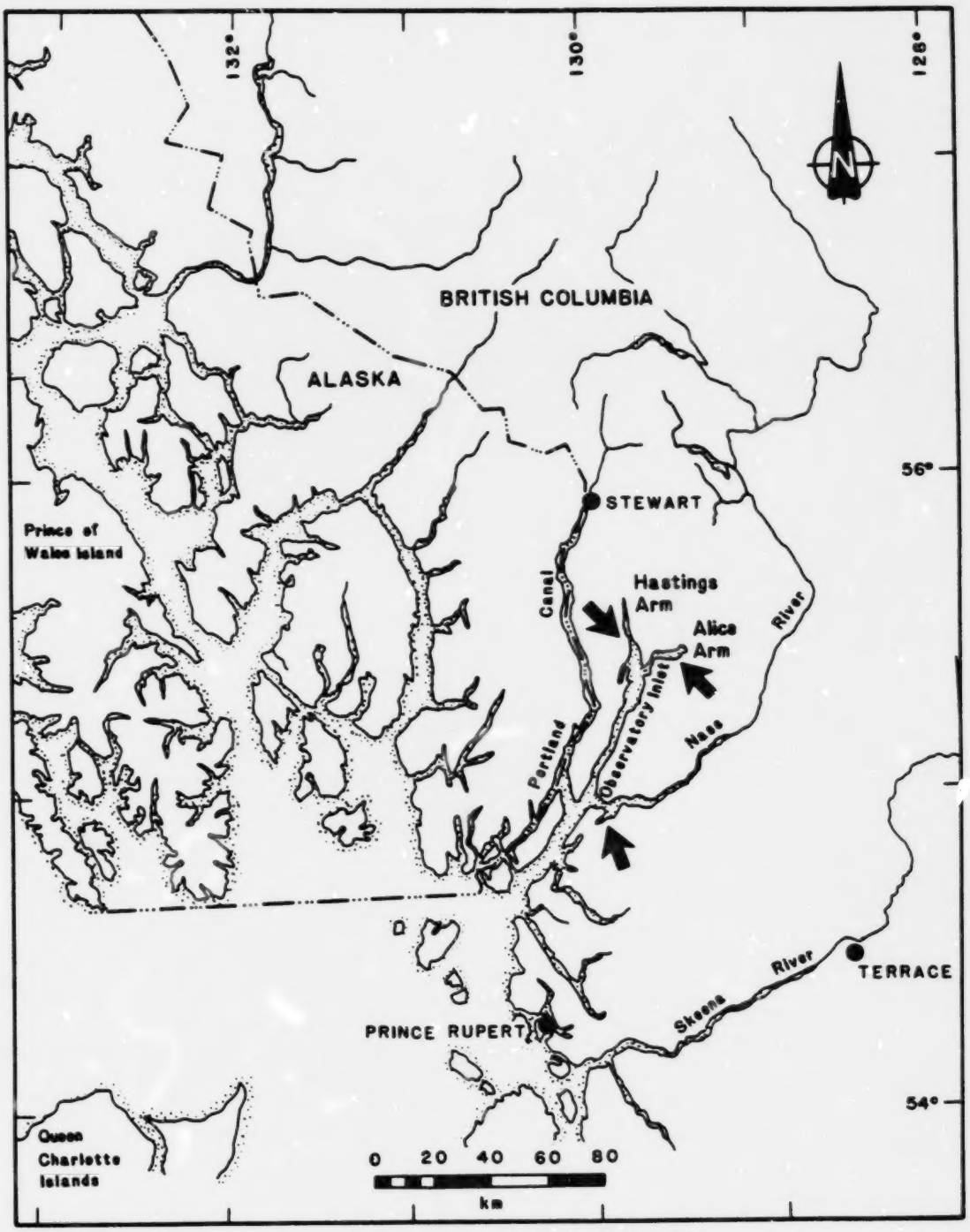

FIGURE 1. Study areas in northern British Columbia.

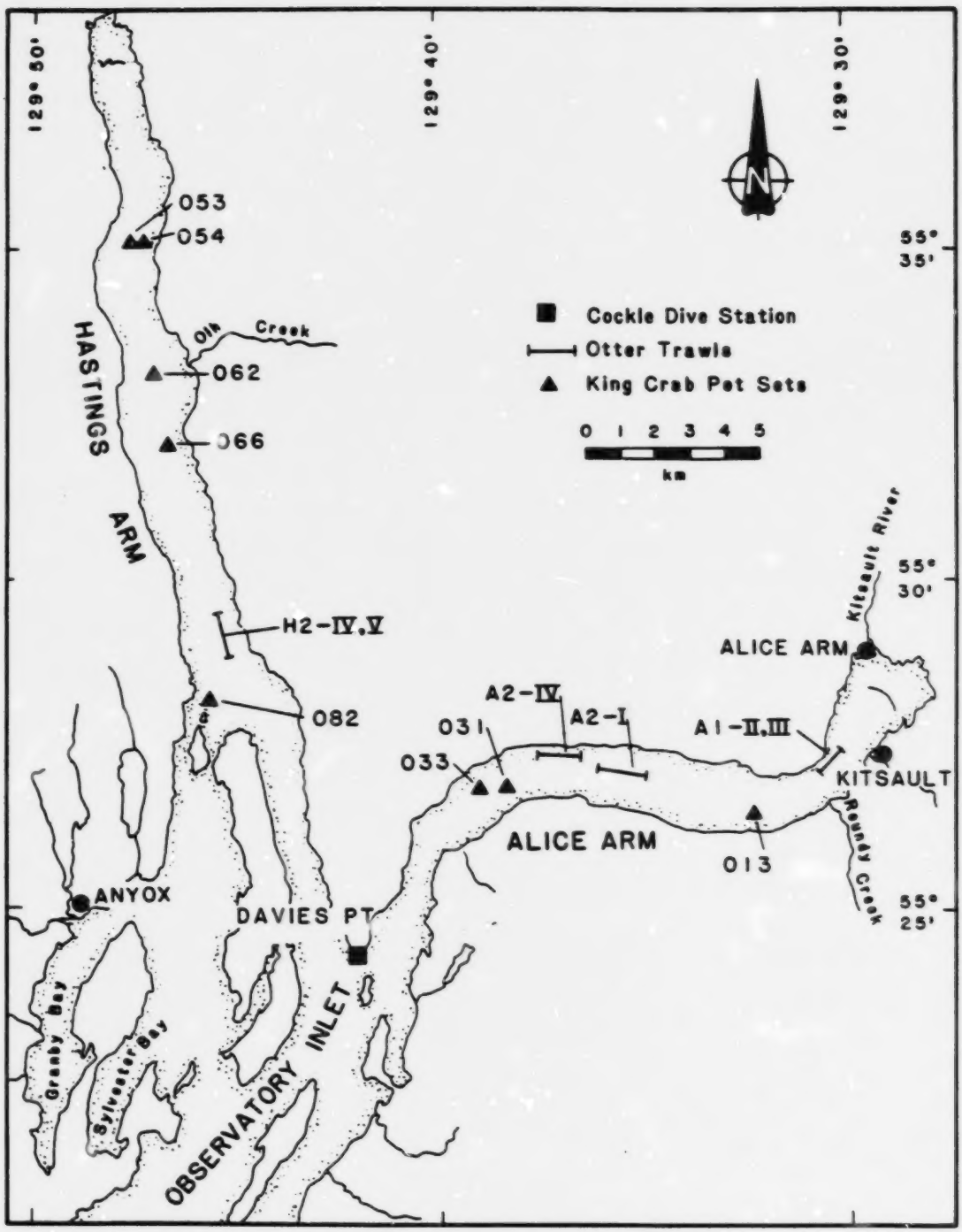

FIGURE 2. Otter trawl, king crab pot and cockle dive stations in Alice Arm, Hastings Arm and Observatory Inlet.

Table 1 List of organisms from Alice Arm, Hastings Arm and Observatory Inlet, B.C., analyzed for trace metal content.

SPECIES	LOCATION	N
MOLLUSCA		
Cockles (*Clinocardium nuttallii*)	Observatory Inlet (Davies Point)	30
ARTHROPODS		
Tanner crab (*Chionoecetes bairdi*)	Alice Arm	3
Golden king crab (*Lithodes aequispina*)	Alice Arm	5
	Hastings Arm	8
Red king crab (*Paralithodes camtschatica*)	Hastings Arm	6

Table 2 Otter trawl coordinates and depths for trawls conducted in Alice and Hastings Arm, 8-10 October, 1983.

TRAWL	DATE	LOCATION (ON BOTTOM)	LOCATION (START UP)	DEPTH (m)
ALICE ARM				
A1-II	8 Oct	55°27.13'N 129°29.87'W	55°27.28'N 129°29.70'W	165
A1-III	8 Oct	55°27.10'N 129°29.97'W	55°27.95'N 129°29.60'W	157-102
A2-I	8 Oct	Not Recorded	52°26.81'N 129°34.35'W	373-358
A2-IV	11 Oct	55°27.00'N 129°35.41'W	55°26.87'N 129°33.90'W	395-356
HASTINGS ARM				
H2-IV	10 Oct	55°31.70'N 129°46.80'W	Not recorded	300-265
H2-V	10 Oct	55°31.00'N 129°46.50'W	55°32.00'N 129°47.00'W	302-293

Table 3 Crab pot locations, depths and soak times in Alice and Hastings Arm, October-November, 1983.

LOCATION	DATE	POT DEPTH (m)	SOAK TIME (h)
ALICE ARM			
AA-13	Oct. 28, 1983	329	23.3
AA-031	Oct. 29, 1983	388	42.8
AA-033	Oct. 29, 1983	388	43.3
HASTINGS ARM			
HA-053	Oct. 31, 1983	238	23.9
HA-054	Oct. 31, 1983	245	24.0
HA-062	Oct. 31, 1983	274	25.6
HA-066	Oct. 31, 1983	305	26.3
HA-082	Nov. 02, 1983	101	45.0

Table 4 Summary of length and weight data for cockles (*Clinocardium nuttallii*) collected from Davies Point, Observatory Inlet, B.C.

Sample Number	Dorsal-Ventral Length (cm)	Anterior-Posterior Length (cm)	Wet Tissue Weight (g)
1	5.4	7.5	58.9
2	5.6	7.1	47.1
3	8.2	8.4	82.0*
4	5.6	7.1	46.4
5	5.9	6.9	48.0
6	6.7	7.2	59.4
7	6.8	7.3	60.8
8	6.4	6.8	54.8
9	7.1	7.8	72.8*
10	7.3	8.0	70.6*
11	7.5	7.7	69.9*
12	6.7	7.6	59.8
13	6.7	6.9	42.9
14	6.8	7.5	50.6
15	6.1	6.5	39.6
16	6.2	7.2	48.2
17	6.1	7.0	43.3
18	6.3	6.7	39.2
19	6.8	7.2	55.4
20	7.0	7.7	65.5
21	7.9	8.7	76.7*
22	6.8	7.3	52.7
23	6.4	7.1	47.6
24	6.6	7.1	57.5
25	6.5	7.1	43.2
26	6.4	7.1	50.0
27	7.2	7.8	69.5
28	5.9	6.4	37.2
29	6.6	7.0	49.6
30	7.3	7.8	70.0

* Some sediment incorporated in sample

TABLE 5 Summary of length, weight, sex and sample site location data for crabs collected from Alice Arm and Hastings Arm, B.C.

Species	Collection Date	Sample I.D.	Sample Location	Weight (g)	Length (mm)	Sex
ALICE ARM						
Golden King Crab (Lithodes aequispina)	08/10/83	LA#1	Trawl A1-III	1693	139	Male
"	11/10/83	LA#5	Trawl A2-IV	2045	143	Male
"	28/10/83	LA#8	Set 013	1850	141	Male
"	29/10/83	LA#13	Set 031	2550	150	Male
"	29/10/83	LA#17	Set 033	1400	142	Female
Tanner Crab (Chionoecetes bairdi)	08/10/83	TC#3	Trawl A1-II	390	103*	Male
"	08/10/83	TC#4	Trawl A2-I	331	105*	Male
"	08/10/83	TC#5	Trawl A2-I	1071	140*	Male
HASTINGS ARM						
Golden King Crab (Lithodes aequispina)	10/10/83	LA#2	Trawl H2-IV	1525	136	Male
"	10/10/83	LA#3	Trawl H2-V	549	114	**Female
"	10/10/83	LA#4	Trawl H2-V	637	98	Male
"	31/10/83	LA#18	Set 053	1350	137	Female
"	31/10/83	LA#19	Set 054	3150	161	Male
"	31/10/83	LA#21	Set 062	2200	152	Male
"	31/10/83	LA#22	Set 066	1050	121	Female
"	31/10/83	LA#23	Set 066	1050	120	Female
Red King Crab (Paralithodes camstchatoca)	02/11/83	RC#1	Set 082	N/R†	104	Female
"	02/11/83	RC#2	Set 082	N/R	120	Female
"	02/11/83	RC#3	Set 082	N/R	118	Female
"	02/11/83	RC#4	Set 082	N/R	111	Male
"	02/11/83	RC#5	Set 082	N/R	151	Male
"	02/11/83	RC#6	Set 082	N/R	141	Male

* Carapace width
** Parasitized female
† Not recorded

TABLE 6 Trace metal data (As, Cd, Cr, Cu, Pb, Mn, Hg, Mo, Ni, Zn) (dry weight) for individual cockles collected from Davies Point, Observatory Inlet, B.C.

Species	N	TRACE METALS (ug/g dry weight)									
		ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MANGANESE	MERCURY	MOLYBDENUM	NICKEL	ZINC
COCKLES (Clino-cardium nuttallii)	1	5.	0.25	2.3	8.0	0.32	15.50	0.05	<0.4	5.	57.5
	1	7.	0.13	1.5	4.7	0.32	13.70	0.06	0.4	13.	78.9
	1	7.	0.20	1.6	4.2	0.17	10.60	0.10	<0.4	5.	57.6
	1	5.	0.18	1.4	4.8	0.38	3.91	0.05	<0.4	10.	51.0
	1	<4.	0.12	1.3	3.4	0.42	13.60	<0.02	<0.4	7.	51.0
	1	7.	0.18	1.3	4.0	0.23	9.10	0.06	<0.4	8.	61.9
	1	6.	0.18	1.0	3.5	0.16	8.14	<0.02	<0.4	10	67.7
	1	8.	0.15	1.2	3.5	0.28	9.34	<0.02	<0.4	11.	53.7
	1	6.	0.18	1.1	3.9	0.16	10.20	0.02	<0.4	7.	79.1
	1	6.	0.16	0.9	3.0	0.26	11.80	0.04	<0.4	7.	55.5
	1	5.	0.19	1.0	3.8	0.27	6.37	0.04	<0.4	7.	51.7
	1	5.	0.18	0.9	3.6	0.41	7.98	0.04	<0.4	4.	64.0
	1	7.	0.17	0.9	4.1	0.27	15.20	0.05	<0.4	4.	60.2
	1	7.	0.21	1.2	4.4	0.25	17.50	0.06	<0.4	6.	71.8
	1	5.	0.19	0.8	3.9	0.39	3.27	0.05	<0.4	3.	52.0
	1	5.	0.19	0.8	3.3	0.27	11.20	0.04	<0.4	5.	50.5
	1	7.	0.19	0.9	4.2	0.38	11.10	0.06	<0.4	3.	57.1
	1	6.	0.16	1.0	3.7	0.29	12.70	0.06	<0.4	8.	52.0
	1	8.	0.16	0.6	3.6	0.30	3.09	0.06	<0.4	3.	66.1
	1	6.	0.18	0.9	3.6	0.24	16.20	0.04	<0.4	4.	68.1
	1	10.	0.45	1.7	4.4	0.27	16.70	0.06	<0.4	5.	81.1
	1	8.	0.16	0.8	3.7	0.16	3.09	<0.02	<0.4	7.	67.6
	1	5.	0.21	0.9	4.7	0.37	13.30	0.06	<0.4	7.	74.8
	1	8.	0.13	0.9	4.1	0.16	6.83	<0.02	<0.4	6.	73.9
	1	7.	0.15	1.2	5.0	0.40	5.76	0.06	<0.4	8.	96.0
	1	9.	0.17	2.2	3.8	0.46	9.50	0.06	<0.4	6.	58.3
	1	<4.	0.32	0.8	3.6	0.20	9.17	0.06	<0.4	8.	73.4
	1	7.	0.14	1.4	3.2	0.29	11.40	<0.02	<0.4	4.	53.0
	1	6.	0.14	0.9	3.3	0.29	13.60	0.06	<0.4	8.	65.7
	1	6.	0.17	1.1	3.1	0.62	2.75	0.02	<0.4	5.	58.2

TABLE 7 Trace metal data (As, Cd, Cr, Cu, Pb, Mn, Hg, Mo, Ni, Zn) (wet weight) for individual cockles collected from Davies Point, Observatory Inlet, B.C.

		TRACE METALS (ug/g wet weight)									
Species	N	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MANGANESE	MERCURY	MOLYBDENUM	NICKEL	ZINC
COCKLES (Clino-cardium nuttallii)	1	0.8	0.038	0.34	1.21	0.049	2.34	0.008	<0.06	0.8	8.65
	1	1.1	0.019	0.21	0.70	0.047	2.01	0.008	0.06	2.0	11.60
	1	0.8	0.025	0.19	0.51	0.021	1.28	0.010	<0.05	0.6	6.93
	1	0.6	0.024	0.18	0.65	0.051	0.58	0.007	<0.06	1.4	6.87
	1	<0.7	0.030	0.20	0.54	0.067	2.17	0.003	<0.07	1.1	8.17
	1	1.2	0.029	0.22	0.65	0.038	1.49	0.009	<0.07	1.3	10.10
	1	0.9	0.029	0.17	0.56	0.026	1.31	0.003	<0.06	1.6	10.90
	1	1.3	0.024	0.20	0.58	0.047	1.54	0.003	<0.06	1.8	8.86
	1	0.9	0.027	0.16	0.59	0.024	1.55	0.003	<0.06	1.0	12.10
	1	0.9	0.024	0.13	0.44	0.038	1.73	0.006	<0.06	1.0	8.17
	1	0.8	0.028	0.15	0.57	0.040	0.95	0.006	<0.06	1.0	7.67
	1	0.8	0.028	0.14	0.56	0.063	1.22	0.006	<0.06	0.5	9.81
	1	1.2	0.031	0.17	0.76	0.050	2.79	0.009	<0.07	0.7	11.10
	1	0.9	0.030	0.17	0.62	0.035	2.46	0.008	<0.05	0.9	10.10
	1	0.8	0.032	0.13	0.65	0.066	0.55	0.009	<0.07	0.6	8.73
	1	1.0	0.035	0.16	0.61	0.050	2.09	0.007	<0.07	0.9	9.41
	1	1.0	0.030	0.14	0.65	0.059	1.72	0.009	<0.06	0.5	8.86
	1	1.0	0.027	0.16	0.64	0.049	2.16	0.010	<0.07	1.3	10.50
	1	1.3	0.027	0.11	0.59	0.049	0.51	0.010	<0.07	0.6	10.90
	1	0.7	0.023	0.12	0.49	0.031	2.16	0.005	<0.05	0.6	9.10
	1	1.1	0.051	0.19	0.49	0.031	1.89	0.007	<0.05	0.6	9.17
	1	1.2	0.025	0.13	0.59	0.026	0.49	0.003	<0.06	1.0	10.70
	1	0.9	0.034	0.15	0.75	0.059	2.12	0.009	<0.06	1.1	11.90
	1	1.1	0.019	0.12	0.58	0.022	0.95	0.003	<0.06	0.9	10.30
	1	1.1	0.023	0.17	0.73	0.059	0.85	0.008	<0.06	1.1	14.10
	1	1.4	0.026	0.33	0.57	0.068	1.42	0.009	<0.06	0.8	8.70
	1	<0.6	0.047	0.12	0.52	0.030	1.33	0.008	<0.06	1.2	10.60
	1	1.2	0.022	0.23	0.50	0.046	1.79	0.003	<0.06	0.7	8.32
	1	1.1	0.023	0.15	0.56	0.048	2.28	0.009	<0.07	1.4	11.00
	1	0.9	0.027	0.17	0.48	0.095	0.42	0.003	<0.06	0.7	8.97

TABLE 8 Trace metal data (As, Cd, Cr, Cu, Pb, Mn, Hg, Mo, Ni, Zn) (dry weight) for individual Red, Golden and Tanner crabs from Alice and Hastings Arm, B.C.

SPECIES	SAMPLE I.D.	N	TRACE METALS (ug/g dry weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MANGANESE	MERCURY	MOLYBDENUM	NICKEL	ZINC
ALICE ARM												
GOLDEN KING CRAB (Lithodes aequispina)	LA#1	1	151.0	0.17	0.9	15.3	<0.08	1.31	0.1	<0.4	<2.0	238.0
	LA#5	1	196.0	0.23	0.5	42.2	<0.08	2.02	0.07	<0.4	<2.0	199.0
	LA#8	1	106.0	0.18	0.5	42.2	<0.08	2.13	-	<0.4	<2.0	229.0
	LA#13	1	112.0	0.20	<0.4	87.2	0.12	1.83	0.16	<0.4	<2.0	193.0
	LA#17	1	179.0	0.20	<0.4	35.7	0.09	5.59	0.13	<0.4	<2.0	206.0
TANNER CRAB (Chionoecetes bairdi)	TC#3	1	49.0	0.16	0.6	19.4	0.37	6.68	0.13	<0.4	<2.0	117.0
	TC#4	1	168.0	<0.04	0.6	27.3	0.20	13.20	0.20	<0.4	<2.0	131.0
	TC#5	1	246.0	0.38	0.5	27.7	0.33	2.95	0.29	<0.4	<2.0	117.0
HASTINGS ARM												
GOLDEN KING CRAB (Lithodes aequispina)	LA#2	1	172.0	0.10	0.6	32.2	0.32	2.49	0.04	<0.4	<2.0	191.0
	LA#3	1	157.0	0.21	0.4	32.3	<0.08	4.22	0.04	<0.4	<2.0	185.0
	LA#4	1	135.0	0.23	0.5	25.0	0.24	5.61	0.02	<0.4	<2.0	192.0
	LA#18	1	164.0	1.2	0.5	77.9	0.18	3.07	0.05	<0.4	<2.0	183.0
	LA#19	1	101.0	0.18	<0.4	98.2	0.23	1.55	0.07	<0.4	<2.0	160.0
	LA#21	1	125.0	0.21	0.6	29.5	0.43	1.13	0.05	<0.4	<2.0	182.0
	LA#22	1	171.0	0.15	0.4	80.8	<0.08	1.66	0.05	<0.4	<2.0	170.0
	LA#23	1	170.0	1.4	0.5	60.1	0.12	2.38	0.05	<0.4	<2.0	179.0
RED KING CRAB (Paralithodes camstchatica)	RC#1	1	65.0	0.19	0.7	101.0	0.15	1.24	0.09	0.4	<2.0	208.0
	RC#2	1	55.0	0.39	0.8	88.9	<0.08	1.67	0.08	0.5	<2.0	208.0
	RC#3	1	45.0	0.23	0.7	106.0	0.38	1.31	0.09	0.6	<2.0	222.0
	RC#4	1	28.0	0.17	0.4	56.3	0.11	0.81	0.15	0.5	<2.0	201.0
	RC#5	1	31.0	0.17	0.5	56.7	0.32	0.84	0.25	0.4	<2.0	177.0
	RC#6	1	38.0	0.25	0.5	95.7	<0.08	0.89	0.25	0.6	<2.0	162.0

TABLE 9 Trace metal data (As, Cd, Cr, Cu, Pb, Mn, Hg, Mo, Ni, Zn) (wet weight) for individual Red, Golden and Tanner crabs from Alice and Hastings Arm, B.C.

SPECIES	SAMPLE I.D.	N	TRACE METALS (ug/g wet weight) ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MANGANESE	MERCURY	MOLYBDENUM	NICKEL	ZINC
ALICE ARM												
GOLDEN KING CRAB (Lithodes aequispina)	LA#1	1	24.9	0.027	0.14	2.52	<0.010	0.22	.016	<0.07	<0.3	39.3
	LA#5	1	32.1	0.038	0.08	6.92	<0.010	0.33	.010	<0.07	<0.3	32.7
	LA#8	1	18.8	0.033	0.09	7.49	<0.010	0.38	-	<0.07	<0.3	40.6
	LA#13	1	14.9	0.026	<0.05	11.50	0.015	0.24	.021	<0.05	<0.2	25.6
	LA#17	1	33.9	0.019	<0.08	6.75	0.020	1.06	.024	<0.08	<0.3	38.9
TANNER CRAB (Chionoecetes bairdi)	TC#3	1	9.0	0.029	0.11	3.53	0.068	1.22	.025	<0.07	<0.3	21.4
	TC#4	1	24.0	<0.006	0.09	3.91	0.028	1.89	.029	<0.06	<0.2	18.8
	TC#5	1	45.1	0.070	0.09	5.07	0.061	0.54	.052	<0.07	<0.3	21.5
HASTINGS ARM												
GOLDEN KING CRAB (Lithodes aequispina)	LA#2	1	25.3	0.015	0.08	4.73	0.047	0.37	.006	<0.06	<0.2	28.1
	LA#3	1	32.3	0.042	0.09	6.61	<0.020	0.86	.008	<0.08	<0.3	37.9
	LA#4	1	25.3	0.044	0.09	4.68	0.045	1.05	.004	<0.08	<0.3	36.0
	LA#18	1	26.0	0.190	0.07	12.40	0.029	0.49	.008	<0.06	<0.3	29.1
	LA#19	1	15.8	0.027	<0.06	15.30	0.036	0.24	.010	<0.06	<0.3	24.9
	LA#21	1	23.7	0.040	0.11	5.59	0.082	0.21	.009	<0.08	<0.3	34.4
	LA#22	1	28.7	0.025	0.07	13.60	<0.010	0.28	.009	<0.07	<0.3	28.5
	LA#23	1	29.5	0.240	0.08	10.40	0.020	0.41	.009	<0.07	<0.3	31.1
RED KING CRAB (Paralithodes camstchatica)	RC#1	1	11.4	0.033	0.13	17.80	0.026	0.22	.020	0.07	<0.3	36.7
	RC#2	1	7.4	0.053	0.11	12.00	<0.010	0.23	.010	0.07	<0.2	28.2
	RC#3	1	7.1	0.036	0.11	16.60	0.059	0.21	.010	0.09	<0.2	34.9
	RC#4	1	5.6	0.034	0.09	11.10	0.022	0.16	.030	0.10	<0.3	39.6
	RC#5	1	5.8	0.032	0.1	10.60	0.059	0.16	.046	0.08	<0.3	33.1
	RC#6	1	8.0	0.052	0.1	20.00	<0.020	0.18	.053	0.13	<0.3	33.8

TABLE 10 Summary of trace metal data in crabs and cockles from Alice Arm, Hastings Arm and Observatory Inlet, B.C..

Common name (Species)	n	TRACE METALS (ug/g) ARSENIC Wet weight $\bar{X} \pm$ S.D (range)	ARSENIC Dry weight $\bar{X} \pm$ S.D (range)	CADMIUM Wet weight $\bar{X} \pm$ S.D (range)	CADMIUM Dry weight $\bar{X} \pm$ S.D (range)	CHROMIUM Wet weight $\bar{X} \pm$ S.D (range)	CHROMIUM Dry weight $\bar{X} \pm$ S.D (range)
MOLLUSCS							
Cockles (Clinocardium nuttallii)	30	N.D.* (<0.6-1.4)	N.D.* (<4-10)	0.028 ± 0.007 (0.019-0.051)	0.19 ± 0.06 (0.12-0.45)	0.17 ± 0.05 (0.11-0.34)	1.2 ± 0.4 (0.6-2.3)
CRUSTACEANS							
Golden King Crab (Lithodes aequispina)	13	25.5 + 6.07 (14.9-33.9)	149.2 + 30.5 (101-196)	0.059 + 0.07 (0.015-0.24)	0.35 + 0.42 (0.10-1.4)	N.D.* (<0.05-0.14)	N.D.* (<0.4-0.9)
Red King Crab (Paralithodes camtschatica)	6	7.55 + 2.10 (5.6-11.4)	43.7 + 14.3 (28-65)	0.04 + 0.010 (0.032-0.053)	0.23 + 0.08 (0.17-0.39)	0.11 + 0.01 (0.09-0.13)	0.6 + 0.15 (0.5-0.8)
Tanner Crab (Chionoecetes bairdi)	3	26.0 + 18.1 (9.0-45.1)	154.3 + 99.2 (49-246)	N.D.* (<0.006-0.07)	N.D.* (<0.04-0.38)	0.09 + 0.01 (0.09-0.11)	0.56 + 0.05 (0.5-0.6)

* Not determined. Values below detection limits precluded calculation of mean and standard deviation.

TABLE 10 (Continued)

Common name (Species)	n	TRACE METALS (ug/g) COPPER Wet weight $\bar{X}$ ± S.D (range)	COPPER Dry weight $\bar{X}$ ± S.D (range)	LEAD Wet weight $\bar{X}$ ± S.D (range)	LEAD Dry weight $\bar{X}$ ± S.D (range)	MANGANESE Wet weight $\bar{X}$ ± S.D (range)	MANGANESE Dry weight $\bar{X}$ ± S.D (range)
MOLLUSCS							
Cockles (Clinocardium nuttallii)	30	0.61 ± 0.14 (0.44 - 1.21)	4.0 ± 0.9 (3.0 - 8.0)	0.046 ± 0.017 (0.021-0.095)	0.30 ± 0.10 (0.16-0.62)	1.54 ± 0.66 (0.42-2.79)	10.1 ± 4.3 (2.75-17.5)
CRUSTACEANS							
Golden King Crab (Lithodes aequispina)	13	8.35 ± 3.9 (2.52-15.3)	50.6 ± 26.9 (15.3-98.2)	N.D.* (<0.01-0.082)	N.D.* (<0.08-0.43)	0.47 ± 0.31 (0.21-1.06)	2.69 ± 1.52 (1.13-5.61)
Red King Crab (Paralithodes camtschatica)	6	14.68 ± 3.96 (10.6-20.0)	84.1 ± 22.1 (56.3-106)	N.D.* (<0.01-0.59)	N.D.* (0.08-0.38)	0.19 ± 0.03 (0.16-0.23)	1.12 ± 0.34 (0.81-1.67)
Tanner Crab (Chionoecetes bairdi)	3	4.17 ± 0.81 (3.53-5.07)	24.8 ± 4.7 (19.4-27.7)	0.052 ± 0.02 (0.028-0.068)	0.3 ± 0.09 (0.2-0.37)	1.22 ± 0.67 (0.54-1.89)	7.6 ± 5.18 (2.95-13.2)

TABLE 10 (Continued)

Common name (Species)	n	TRACE METALS (ug/g) MERCURY Wet weight X ± S.D (range)	MERCURY Dry weight X ± S.D (range)	MOLYBDENUM Wet weight X ± S.D (range)	MOLYBDENUM Dry weight X ± S.D. (range)	NICKEL Wet weight X ± S.D (range)	NICKEL Dry weight X ± S.D (range)	ZINC Wet weight X ± S.D (range)	ZINC Dry weight X ± S.D (range)
MOLLUSCS									
Cockles (Clinocardium nuttallii)	30	0.007 ± 0.003 (0.003-0.010)	N.D.* (<0.02-0.1)	N.D.* (<0.05-<0.07)	N.D.* (<0.4-0.4)	0.96 ± 0.42 (0.5-2.0)	6.5 ± 2.4 (3-13.0)	9.74 ± 1.61 (6.93-14.1)	64 ± 11 (50.5-96.0)
CRUSTACEANS									
Golden King Crab (Lithodes aequispina)	13	0.011 + 0.006 (0.006-0.024)	0.069 + 0.04 (0.02-0.16)	N.D.* (<0.05-<0.08)	N.D.* (<0.4)	N.D.* (<0.2-<0.3)	N.D.* (<2.0)	32.8 + 5.4 (24.9-40.6)	192.8 + 21.6 (170-238)
Red King Crab (Paralithodes camtschatica)	6	0.028 + 0.018 (0.01-0.053)	0.15 + 0.08 (0.08-0.25)	0.09 + 0.02 (.07-0.13)	0.5 + 0.09 (0.4-0.6)	N.D.* (<0.2-<0.3)	N.D.* (<2.0)	34.4 + 3.8 (28.2-39.6)	196.3 + 22.4 (162-222)
Tanner Crab (Chionoecetes bairdi)	3	0.035 + 0.015 (0.025-0.052)	0.21 + 0.08 (0.13-0.29)	N.D.* (<.06-<.07)	N.D.* (<0.4)	N.D.* (<0.2-<0.3)	N.D.* (<2.0)	20.6 + 1.53 (18.8-21.5)	121.7 + 8.1 (117 - 131)

* Not determined. Values below detection limits precluded calculation of mean and standard deviation.

APPENDIX I List of heavy metals analyzed and their detection limits in tissues.

Metal	Abbre-vation	Method of Analyses	Achievable Detection Limits In tirsue† (ug/g) dry weight
Arsenic	As	I.C.A.P.	4.0 ± 0.2
Cadmium	Cd	I.C.A.P.	0.2 ± 0.05
Cadmium	Cd	Flamless A.A. spectrometry	0.04 ± 0.05
Copper	Cu	I.C.A.P.	0.4 ± 0.03
Chromium	Cr	I.C.A.P.	0.4 ± 0.03
Lead	Pb	I.C.A.P.	2.0 ± 0.2
Lead	Pb	Flamless A.A. spectrometry	0.08 ± 0.02
Manganese	Mn	I.C.A.P.	0.08 ± 0.003
Mercury	Hg	Mercury monitor (cold vapor technique)	0.10 ± 0.02
Molybdenum	Mo	I.C.A.P.	0.4 ± 0.05
Nickel	Ni	I.C.A.P.	2.0 ± 0.3
Zinc	Zn	I.C.A.P.	0.2 ± 0.05

† Metal detection limits in tissue were calculated assuming a dilution of 0.3 g (dry weight) of tissue in 25 ml liquid during sample preparation. Any variation in the amount of tissue used in sample preparation results in a corresponding variation in tissue detection limits (less tissue leading to a higher detection limit). Thus detection limits may actually vary somewhat with sample preparation and for this reason, detection limits reported here should be viewed as estimates only.

APPENDIX II Certified and analyzed metal levels in reference tissue standards.

Reference Standard		Certified (ug/g)	Obtained (ug/g) Replicates 1	2	3	4
NBS-1566						
Oyster Tissue	As	13.4 ± 1.9	14.0	15.0	14.0	14.0
	Cd	3.5 ± 0.4	3.3	3.2	3.3	3.2
	Cr	0.69 ± 0.27	1.0	0.7	0.7	0.8
	Mn	17.5 ± 1.2	17.0	16.8	16.5	16.3
	Ni	1.03 ± 0.19	<2.0	<2.0	<2.0	<2.0
	Pb	0.48 ± 0.04	<2.0	<2.0	<2.0	<2.0
	Cu	63.0 ± 3.5	61.7	63.6	62.8	62.3
	Zn	852.0 ± 14.0	794.0	813.0	796.0	791.0
NBS-1577						
Bovine Tissue	Cd	0.27 ± 0.04	0.3	0.3	0.2	0.2
	Mn	10.3 ± 1.0	10.3	10.0	9.98	9.94
	Mo	3.1 ± 0.5	3.4	3.6	3.3	3.3
	Pb	0.34 ± 0.08	0.35	0.35	-	-
	Cu	193.0 ± 10.0	199.0	194.0	193.0	189.0
	Zn	130.0 ± 10.0	137.0	134.0	133.0	129.0

APPENDIX III Canadian Health and Welfare Guidelines* and Food and Drug Regulations**

Years Regulations/ Guidelines Effective	Food Category	ug/g wet weight††† Mercury	Arsenic	Lead	Copper	Zinc
1975-1978	Marine and Fresh Water Animal Products*		5*	10*	100*	100*
1979-	Fish Protein**		3.5**	0.5**	-	-
	Edible fish tissue***	0.5***				

* Marine and freshwater animal products include fish, crustaceans, molluscs, other marine invertebrates, marine mammals and frogs.

** Regulations which pertain to arsenic and lead concentrations in fish protein prepared by (i) extracting water, fat, and other soluble components through the use of isopropynol alcohol from fresh whole edible fish of the order Clupeiformes, families Clupeidae and Osmeridae and the order Gadiformes, family Gadidae, or from trimmings resulting from the filleting of such fish when eviscerated and (ii) drying and grinding the resultant protein concentrate (persuant to Section B.21.027 of the Food and Drug Act). These regulations supercede those previously identified for marine and freshwater animal products. No regulations presently exist for acceptable levels of metals in edible fish tissue. As extractable dried fish protein and edible fish tissue are not the same, comparisons between the two have not been made and regulations have been presented solely for information.

*** Health and Welfare Administrative Guideline, which refers to the acceptable mercury concentration in edible wet weight fish tissue. This guideline is directly comparable to wet weight mercury concentrations in edible (muscle) tissue of crab.

††† Although the regulations pertain specifically to an alcohol extractable dried fish protein product the regulations and guidelines are reported on a wet weight basis. This is because during sample preparation for metals analyses, aliquots of homogenized tissue are sampled and weighed accurately prior to drying and digestion. As the percent moisture is not determined (ie: the sample is not re-weighed after drying) results must be presented on the basis of the initial tissue wet weight.

APPENDIX IV Mean values for tissue metal levels reported in cockles from Alice Arm and Davies Point (from Amax of Canada Ltd., 1983)
TRACE METALS (ug/g dry weight)

SPECIES	DATE	SAMPLE LOCATION	N*	CADMIUM	COPPER	ZINC	MOLYBDENUM	LEAD	ARSENIC
COCKLES									
(Clinocardium nuttallii)	1982	Davies Point	11	0.95	3.13	71.86	<5.16	<2.58	5.83
(Clinocardium ciliatum)	1982	Alice Arm, AAN	2	1.79	51.73	80.53	<6.99	<3.49	8.95
		AAS	2	2.73	50.50	102.88	<12.45	11.33	7.46
		BBN	2	2.53	51.90	89.07	5.78	<2.89	8.70
		BBS	2	2.52	52.90	108.30	35.80	10.19	6.94
		CCN	4	2.79	70.75	120.30	<7.29	<3.64	7.44
		CCS	7	3.00	44.40	89.12	<6.92	<3.46	5.70
		FFN	11	3.13	46.70	87.03	<5.56	<2.78	9.99
		FFS	11	1.79	25.80	74.79	<5.95	<2.97	6.39
		HHN	11	0.99	20.29	61.03	<4.59	<2.30	10.85
		HHE	11	1.01	22.78	69.52	<4.72	<2.47	7.77

*N = number of analyses reported.

APPENDIX V Tissue metal levels (ranges) reported in other bivalves from Alice Arm and southern B.C. locations

SPECIES	DATE	SAMPLE LOCATION	TRACE METALS (ug/g dry weight) CADMIUM	COPPER	ZINC	MOLYBDENUM	LEAD	ARSENIC	
CLAMS									
(Mya arenaria)	1980	Ferry Pen., B.C.	(0.70-1.60)	(12-31)	(76-164)	(.40-1.10)	(<0.05-2.0)	(4.0-11.0)	Goyette and Christie, 1982
LITTLENECK CLAMS									
(Protothaca staminea)	1982	Mudge Island, B.C. Gabriola Island, B.C.	(<0.5-0.5)	(9.6-12)	(49-55)	-	(<3.0)	-	Harbo et al, 1983
HORSE CLAMS									
(Tresus capax)	1971	Jordan River, Sooke, B.C.	0.33	17.0	43.0	-	0.8	-	Harbo et al, 1983
CLAMS	1971	Port Hardy, Hardy Bay		(2.3-20.5)	(79.1-119.5)		27.8		Harbo et al, 1983
BUTTER CLAMS									
(Saxidomus gigantus)	1971	Port Hardy, Hardy Bay	0.3	17.0	59.0		0.8		Harbo et al, 1983
MUSSELS									
(Mytilus edulis)	1977	Alice Arm, B.C.	(4.8-6.9)	(9-13)	(99-130)	-	(1.1-5.0)	-	Goyette and Christie, 1982
	1978	Alice Arm, B.C.	(3.5-7.6)	(13-31)	(59-107)	-	(<4.3-7.8)	-	Goyette and Christie, 1982
	1982	Alice Arm, B.C.	(2.96-5.37)	(6.23-9.96)	(61.4-90.8)	(<4.14-<5.47)	(<2.07-4.75)	(7.41-9.54)	Amax of Canada, 1982
	1973	Crescent Beach, B.C.	2.0	12.0	100.0	-	1.0	-	Harbo et al, 1983
	1972	Victoria, B.C.	2.0	12.0	150.0	-	4.0	-	Harbo et al, 1983
	1972	Gold River, B.C.	3.0	8.0	76.0	-	-	-	Harbo et al, 1983
OYSTERS									
(Crassostrea gigas)	1971	Campbell River, B.C.	8.7	(76-1000)	(2300-22000)	-	1.0	-	Harbo et al, 1983
	1976	Mudge Island, Gabriola Is.	(4.3-9.9)	(54-140)	(810-2900)	-	-	-	Harbo et al, 1983
	1977	Mudge Island, Gabriola Is.	(2.9-8.5)	(32-130)	(620-4800)	-	-	-	Harbo et al, 1983
SCALLOPS									
(Hinnites gigantus)	1973	Alert Bay	11.0	3.0	59.0	-	<1.0	-	Harbo et al, 1983
	1972	Powell River	15.0	5.0	100.0	-	<1.0	-	Harbo et al, 1983
	1972	Hornby Island	7.8	2.0	90.0	-	<1.0	-	Harbo et al, 1983
	1971	Saturna Island	-	0.59	72.0	-	<0.66	-	Harbo et al, 1983
COCKLES									
(Clinocardium nuttali)	1973	Crescent Beach, B.C.	<0.5	11.0	160.0	-	<1.0	-	Harbo et al, 1983

APPENDIX VI Summary of metal levels in bivalves (pelecypods) reported from selected coastal locations throughout the world.

Organism	Metal	Concentration (ug/g) dry wt.	Locality	Reference
	Arsenic			
Pelecypods		2.3-2.6	New York	Klusek et al. (1982)
Pelecypods		0.05-0.12*	Gulf of Mexico	Lytle et al. (1982)
Pelecypods		4.0-15.0	Newfoundland	Penrose (1975)
	Cadmium			
Pelecypods		0.6-1.1	New York	Klusek et al. (1982)
Oysters and clams		<0.05-1.6*	Gulf of Mexico	Lytle et al. (1982)
Bay mussels (Mytilus edulis)		1.5-11.5	Oregon	LaTouche et al. (1982)
Pelecypods		0-152.5	Australia	Klumpp et al. (1982)
Pelecypods		0.23-1.11*	Australia	Woolton et al. (1982)
Scallop (Pecten alka)		0.52-10.73*	Australia	Walker et al. (1982)
Oysters (Crassostrea gigas)		2.0-2.3	Tasmania	Thomson (1982)
Clams (Scrobiccularia plana)		0.57-32.4	United Kingdom	Luoma et al. (1982)
Mussels (Mytilus edulis)		0-150	Denmark	Poulsen (1982)
Oysters (Crassostrea gigas)		1-2.8*	South Africa	Watling et al. (1982)
Oysters (Crassostrea gigas)		2.5-3.7	South Africa	Watling et al. (1982)
Mussels (Mytilus edulis)		2.8-174.3	Australia	Talbot et al. (1976)
Pelecypods		0.08-3.58	Massachusetts	Kerfoot et al. (1976)
Scallop (Pecten alka)		0.7-600.0*	California	Young et al. (1976)
	Copper			
Bay mussels (Mytilus edulis)		3.7-18.3	Oregon	LaTouche et al. (1982)
Oysters and mussels		10-54	Hong Kong	Phillips et al. (1981)
Pelecypods		0.53-78.6	Australia	Klumpp et al. (1982)
Mussels (Mytilus edulis)		1.03-4.91*	Australia	Woolton et al. (1982)
Oysters (Crassostrea gigas)		10-370	Tasmania	Thomson (1982)
Oysters (Crassostrea gigas)		0.3-119*	South Africa	Watling (1982)
Clams (Scrobiccularia plana)		17-372	United Kingdom	Luoma et al. (1982)
Pelecypods		6.0	New York	Klusek et al. (1982)
Oysters and clams		2.46-31.5*	Gulf of Mexico	Lytle et al. (1982)
Mussels (Mytilus edulis)		14-69	California	Alexander et al.(1976)
Mussels (Mytilus edulis)		5.5-154	France	Fowler et al. (1976)
	Chromium			
Mussels (Mytilus edulis)		1-2	New York	Klusek et al. (1982)
Oysters and clams		<0.1*	Gulf of Mexico	Lytle et al. (1982)
Oysters (Crassostrea gigas)		<0.1-4.6*	South Africa	Watling et al. (1982)
Mussels (Mytilus edulis)		0.87-5.86*	Australia	Woolton et al. (1982)
Mussels (Mytilus edulis)		0.8-61.0	California	Alexander et al.(1976)
Mussels (Mytilus edulis)		0.5-288.0	France	Fowler et al. (1976)

* wet weight

APPENDIX VI (Continued)

Organism	Metal	Concentration (ug/g) dry wt.	Locality	Reference
	Lead			
Pelecypods		0.6-1	New York	Klusek et al. (1982)
Oysters and clams		<0.5*	Gulf of Mexico	Lytle et al. (1982)
Oysters (Crassostrea gigas)		0.01-1.18*	South Africa	Watling (1982)
Pelecypods		0-40.3	Australia	Klumpp et al. (1982)
Mussels (Mytilus edulis)		0.37-6.47*	Australia	Woolton et al. (1982)
Pelecypods		0.5-30	Tasmania	Thomson (1982)
Mussels (Mytilus edulis)		0.27-42.0	California	Chow (1976)
Mussels (Mytilus edulis)		2.7-117.0	France	Fowler et al. (1976)
Pelecypods		5-19	England	Boyden (1975)
Mussels (Mytilus edulis)		2.4-88	California	Alexander et al.(1976)
	Manganese			
Bay mussels (Mytilus edulis)		2.7-7.5	Oregon	LaTouche et al. (1982)
Oysters (Crassostrea gigas)		0.1-2.2*	South Africa	Watling et al. (1982)
Pelecypods		3.0-18	England	Boyden (1975)
Mussels (Mytilus edulis)		3.3-69.8	France	Fowler et al. (1976)
Oysters (Crassostrea gigas)		2-16	South Africa	Watling et al. (1976)
	Mercury			
Mussels (Mytilus californius)		0.07-2.5	California	Flegal et al. (1981)
Mussels (Mytilus californius)		0.31-0.32	Oregon	Flegal et al. (1981)
Mussels (Mytilus californius)		0.08-0.14	Washington	Flegal et al. (1981)
Pelecypods		0.09-0.11	New York	Klusek et al. (1982)
Pelecypods		0.08-2.26	United Kingdom	Langson (1981)
Scallops (Pecten alka)		0.01-0.09*	Australia	Walker et al. (1982)
Pelecypods		0.02	Hawaii	Klemmer et al. (1976)
Oysters (Crassostrea virginica)		0.13-0.175	Maryland	Sayler et al. (1975)
Pelecypods		0.02	Finland	Nuorteva et al. (1975)
	Molybdenum			
Oysters and clams		<2	Gulf of Mexico	Lytle et al. (1982)
	Nickel			
Bay mussels (Mytilus edulis)		2.1-8.3	Oregon	LaTouche et al. (1982)
Clam (Prototheca staminea)		1.15-2.38	Washington	Hardy et al. (1982)
Oysters and clams		<0.2*	Gulf of Mexico	Lytle et al. (1982)
Pelecypods		1.3-4.0	New York	Klusek et al. (1892)
Oysters (Crassostrea gigas)		0.01-0.91*	South Africa	Watling et al. (1982)
Pelecypods		0.321	Australia	Klumpp et al. (1982)
Mussels (Mytilus edulis)		0.99-4.66*	Australia	Woolton et al. (1982)

* wet weight

APPENDIX VI (Continued)

Organism	Metal	Concentration (ug/g) dry wt.	Locality	Reference
	Nickel (Cont.)			
Pelecypods		2-174	England	Boyden (1975)
Mussels (Mytilus edulis)		0.9-14.1	France	Fowler et al. (1976)
Mussels (Mytilus edulis)		3.3-20	California	Alexander et al.(1976)
	Zinc			
Bay mussels (Mytilus edulis)		34-196	Oregon	LaTouche et al. (1982)
Pelecypods		70-80	New York	Klusek et al. (1982)
Pelecypods		76.5-821*	Gulf of Mexico	Lytle et al. (1982)
Mussels (Mytilus edulis)		12-140*	France	Gutierrez-Galindo (1981)
Oysters (Crassostrea gigas)		18-1202*	South Africa	Watling et al. (1982)
Pelecypods		22.9-2940	Australia	Klumpp et al. (1982)
Mussels (Mytilus edulis)		12.73-70.56*	Australia	Woolton et al. (1982)
Oysters (Crassostrea gigas)		500-7500	Tasmania	Thomson (1982)
Oysters and mussels		56-116	Hong Kong	Phillips et al. (1981)
Mussels (Mytilus edulis)		97-644	France	Fowler et al. (1976)
Oysters (Crassostrea gigas)		396-886	South Africa	Watling et al. (1976)
Mussels (Mytilus edulis)		40-110	California	Alexander et al.(1976)
Pelecypods		94-6060	England	Boyden (1975)
Pelecypods		0.5-900*	New Zealand	Nielsen et al. (1975)

* Wet weight